STUDIES FOR STUDENTS

THE CONSTITUENTS OF METEORITES. I

ELEMENTS

THE following elements have by good authorities been reported as detected in meteorites by means of chemical or spectroscopic examination:

Aluminum	Helium	Potassium
Antimony	Hydrogen	Selenium
Argon	Iodine	Silicon
Arsenic	Iron	Strontium
Barium	Lead	Sodium
Bismuth	Lithium	Sulphur
Calcium	Magnesium	Thallium
Carbon	Manganese	Tin
Cerium	Molybdenum	Titanium
Chlorine	Nickel	Tungsten
Chromium	Nitrogen	Uranium
Cobalt	Oxygen	Vanadium
Copper	Palladium	Zinc
Didymium	Phosphorus	

Many of these, however, occur only as traces, while others may possibly have been introduced by terrestrial agencies. The following list will be therefore more satisfactory as giving the primary and fundamental elements known to enter into the composition of meteorites:

Aluminum	Hydrogen	Phosphorus
Calcium	Iron	Potassium
Carbon	Magnesium	Silicon
Chlorine	Manganese	Sodium
Chromium	Nickel	Sulphur
Cobalt	Nitrogen	
Copper	Oxygen	

It will be of interest to compare the more important of these in

the order of their relative abundance, with the eight most important elements of the earth's crust placed in similar order. The list of the latter is taken from Roscoe and Schorlemmer.[1]

METEORIC SERIES	TERRESTRIAL SERIES
1. Iron	1. Oxygen
2. Oxygen	2. Silicon
3. Silicon	3. Aluminum
4. Magnesium	4. Iron
5. Nickel	5. Calcium
6. Sulphur	6. Magnesium
7. Calcium	7. Sodium
8. Aluminum	8. Potassium

It should be remembered in drawing conclusions from the above list that the elements of cosmic matter in its entirety are here compared with the elements of only the crust of the earth; further, that the meteoritic matter now known probably does not show a true proportion of stony matter. As I have shown elsewhere,[2] the iron meteorites are much more likely to be known and preserved than the stony. It is probable, therefore, that if the average composition of meteoritic matter were known, iron would not occupy so high a place as it does in the above table. The relative excess of magnesium and nickel, and scarcity of aluminum and calcium in meteoritic, as compared with terrestrial, matter may be due to the same cause.

COMPOUNDS

The elements of meteorites chiefly occur combined. The exceptions are iron, nickel, cobalt, and copper, all of which occur largely in the form of alloys, carbon, and the gases, hydrogen, and nitrogen, probably held as elements in the pores of meteorites.

The compounds of meteorites according to the mineralogical names by which they are generally known, and roughly in the order of their relative abundance, are as follows, the minerals not occurring upon the earth being printed in italics:

[1] Treatise on Chemistry, Vol. I. [2] JOUR. GEOL., Vol. V, p. 126.

ESSENTIAL	ACCESSORY
Nickel-iron	Included gases
Chrysolite	Iron sulphide
Orthorhombic pyroxene	*Schreibersite*
Monoclinic pyroxene	Graphite
Plagioclase	Cohenite
Maskelynite	Glass
	Chromite
	Amorphous carbon
	Diamond
	Daubreelite
	Tridymite
	Lawrencite
	Magnetite
	Oldhamite
	Hydro carbons

A brief account will be given of each of these.

Nickel-iron.—This is the most widely distributed constituent of meteorities and in quantity it exceeds all the others combined. It makes up practically the entire mass of all the iron meteorites, the larger part of the mass of the iron-stone meteorites and is found in nearly all, though not all, the stone meteorites. It is an alloy of iron and nickel in which the percentage of nickel varies from about 6 per cent. to about 20 per cent. Some iron masses claimed to be meteorites contain a higher percentage and some authorities regard the nickel-iron of most stone meteorites as generally containing from 20 to 40 per cent. of nickel, but this is somewhat uncertain. From 0.5 to 2 per cent. of cobalt always accompanies the nickel, as well as .006 to .02 per cent. of copper. Traces of manganese and tin are also often found. The terrestrial nickel-iron of the Greenland basalts differs from that of meteorites in having a lower percentage of nickel (0.25 to 4 per cent.) and in containing a considerable amount (3 per cent.) of carbon. The terrestrial nickel-irons known as awaruite and josephinite contain higher percentages of nickel than the meteoritic, the percentages being 67.7 per cent. and 30.5 per cent. respectively. In color, meteoritic nickel-iron varies from iron or steel-gray to silver-white, according to the percentage of

nickel present. In hardness and tenacity the nickel-iron of different meteorites varies greatly. That of some meteorites is harder than steel, that of others softer than wrought iron. That of some meteorites is so brittle as to break in pieces with a blow of the hammer, that of others so malleable that it can be worked into implements of various shapes. Nickel-iron is strongly magnetic and some iron meteorites exhibit polarity due perhaps to induction of the magnetism of the earth. The specific gravity of nickel-iron ranges between 7.6 and 7.9. It is dissolved at ordinary temperatures by the common acids, by solutions of copper sulphate, by copper chloride, by mercuric chloride, by bromine water, by copper ammonium chloride, and by a few other reagents. Some masses of nickel-iron when placed in neutral solutions of copper sulphate reduce the latter, while others do not. The former are known, according to the terms first used by Wöhler, as active, the latter as passive irons. Nickel-iron oxidizes rapidly when exposed to the atmosphere, the rapidity decreasing, however, with increase in the percentage of nickel. In regard to the manner of occurrence of the nickel-iron it may be noted that in the iron meteorites it forms a compact mass except in so far as it is interrupted by inclusions of other minerals. In the iron-stone meteorites all gradations occur from a continuous network to isolated grains. In the stone meteorites it is present in the latter form. A more or less lineal arrangement of these grains, recalling Widmanstätten figures, is often observed in the stone meteorites. When the substance occurs in grains, whether large or small, the shape of these is usually very uneven, being sometimes more or less rounded but generally irregularly branching. Sometimes regular forms such as cubes and octahedrons may be observed. In the Ochansk meteorite, von Siemaschko observed actual crystals made up of a combination of the cube, octahedron, dodecahedron, and a tetrahexahedron. Other cuboidal forms have been observed. The two or possibly three subordinate alloys (kamacite, taenite, and plessite) of which nickel-iron is composed have been described in a previous article and their composition given.

Chrysolite.—This is, next to nickel-iron, the chief mineral constituent of meteorites. It is found in all the iron-stone and nearly all the stone meteorites and makes up a large part of their mass. It occurs as crystals and as rounded and angular grains. In the group of iron-stone meteorites known as pallasites it is porphyritically developed in the nickel-iron; in other iron-stone meteorites it forms together with pyroxene a granular aggregate filling the meshes of a network of nickel-iron. In the chondritic meteorites the manner of its occurrence has already been described. Crystals occurring in cavities or isolated by dissolving adjacent nickel-iron lend themselves readily to goniometric measurement. A total of twenty forms, similar to those found on terrestrial chrysolite has thus been identified. The color of the mineral is usually the typical olive-green of terrestrial chrysolite but may vary to honey-yellow or red. Much of the meteoritic chrysolite is characterized by an abundance of opaque inclusions often regularly arranged. Intergrowths with a colorless to dark brown glass are also common, especially in the chrysolite of chondritic meteorites. Gas pores are rare. Alteration products so common to terrestrial chrysolite are entirely lacking. Much of the chrysolite shows a strong tendency to fissuring, especially in thin sections. Well-marked cleavage is not common. Numerous analyses of mechanically separated chrysolite show a composition similar to that of the terrestrial mineral. The percentage of Fe in these analyses shows variations from about 10 per cent. to about 30 per cent. One feature of the composition of meteoric chrysolite which seems at first difficult to account for, is an almost entire lack of nickel oxide. This, as is well known, is a very constant constituent of terrestrial chrysolite. Daubrée has shown, however, that an absence of nickel from meteoritic chrysolite should be expected, since nickel has less affinity for oxygen than iron and would not be attacked until the latter was completely oxidized. While terrestrial iron has been completely oxidized that of meteorites has not. The correctness of this explanation has further been shown experimentally by fusing terrestrial chrysolite with pyroxene in

the presence of a reducing agent. The nickel of the chrysolite then formed an alloy with the iron of the pyroxene. The siliceous portion of meteorites that is soluble in hydrochloric acid may for the most part be considered chrysolite, since numerous analyses of this portion give results corresponding in composition to this mineral.

Orthorhombic pyroxenes.—The minerals of this group are next in abundance to chrysolite as a constituent of meteorites. They form an essential part of nearly all stone meteorites and are not lacking in the iron-stone meteorites. At least four meteorites consist of orthorhombic pyroxenes alone. These are the meteorite of Bishopville, practically composed of enstatite alone, and those of Manegaon, Ibbenbühren and Shalka, which consist essentially of hypersthene. The color of the orthorhombic pyroxenes varies from colorless through white to various shades of green. Often the mineral has the typical color of chrysolite. In thin section the pyroxene is colorless to slightly colored. Its habit is usually prismatic but it may also occur as rounded grains. Crystals with well defined planes have been observed in the Breitenbach, Bustee, Manegaon and other meteorites. A total of thirty-two forms has thus been identified and the axial relations found to correspond with those of terrestrial hypersthene. Prismatic, macrodiagonal and brachydiagonal cleavages are recognizable. It is especially characteristic of the mineral to form eccentric, radiating, polysomatic chondri, the structure of which has been described in a previous article.

Numerous chemical analyses of mechanically separated orthorhombic pyroxenes have been made. These show all gradations between the compositions represented by the formulas $MgSiO_3$ (enstatite) (Mg, Fe) SiO_3 (bronzite) and (Fe, Mg) SiO_3 (hypersthene). The portion insoluble in acids, of meteorites consisting essentially of nickel-iron, chrysolite and orthorhombic pyroxenes, may be considered to be essentially the latter, as shown by numerous analyses which give results corresponding with the pyroxene formula. The orthorhombic

pyroxenes of meteorites are thus seen to be entirely comparable to the terrestrial minerals of the same name.

Monoclinic pyroxenes.— Two kinds of monoclinic pyroxenes have been identified in meteorites, the first bearing iron and alumina, the second free from alumina and nearly free from iron. The first may be considered similar to terrestrial augite, the second to terrestrial diopside. Augite has been identified in many meteorites, diopside positively only in one. Crystals of meteoritic augite have been measured goniometrically and eight forms similar to those of terrestrial augite found. As a rule, however, the augite occurs as grains or splinters. It varies from brown to green in color, in some meteorites is pleochroic in thin section in others not at all. Parting parallel to the base, owing to repeated twinning, is common and characteristic. It is sometimes regularly intergrown with orthorhombic pyroxene. Inclusions of glass and black dust are common. Pyroxene resembling diopside was identified by Maskelyne in the Bustee meteorite. It occurred in grains and splinters and was of a gray to violet color. A few goniometric measurements were possible. Analysis showed the composition to be that of a calcium-magnesium pyroxene. Crystals and grains from a few other meteorites may perhaps be referred to diopside but the determination is not certain.

Plagioclase.—Of the minerals of the feldspar group, anorthite may be mentioned as forming an essential constituent of the classes of stone meteorites known as eukrites and howardites and as occurring in others. It forms according to Rammelsberg about 35 per cent. of the stones of Juvinas and Stannern. Of the other members of the plagioclase series, albite, oligoclase and labradorite have been reported in single meteorites, but in most cases where plagioclase has been found the species has not been determined. Orthoclase has not yet been identified in any meteorite. Crystals of anthortite from the Jonzac meteorite reach a length of 1^{cm}. From the druses of the Juvinas meteorite anorthite crystals were obtained which served for goniometric measurement, eight forms being thus identified. Some

anorthite crystals show twinning according to the Carlsbad law and in the Llano del Inca and Doña Inez meteorites twins according to the albite and pericline laws were found. The mineral is sometimes white and sometimes colorless and in luster varies from dull to vitreous. Inclusions nearly always abound and they are generally regularly arranged. The inclusions are chiefly colorless glass, but sometimes brownish glass and opaque grains occur. Analyses of mechanically isolated anorthite have been made which show a composition similar to that of terrestrial anorthite. CaO amounts to about 18 per cent. in these analyses.

Calculating from analyses Tschermak concludes the feldspar of the stone of Gopalpur to be oligoclase, Lindstrom that of Hessle to be the same and Schilling that of Tennasilm to be labradorite. The presence of plagioclase other than anorthite has been proved by microscopical and chemical examination of other meteorites, but the species have rarely been determined. Such feldspars occur as lath-shaped individuals and as grains and splinters. Inclusions are much less common than in anorthite. Rounded, elongated inclusions referred by Tschermak to chrysolite and bronzite are, however, quite characteristic. Gas inclusions seem to be more abundant in the feldspars of meteorites than in any other constituent, though even here they are rare.

Maskelynite.—This is an isotropic, colorless, though becoming milky through alteration, transparent mineral of vitreous luster and conchoidal fracture. Its hardness is somewhat over 6; specific gravity 2.65. It has no cleavage but shows occasional irregular cracks and striæ similar to those of plagioclase. Inclusions of magnetite and augite are arranged in apparent zones. The mineral is slightly decomposed by hydrochloric acid. Thin splinters fuse, but with difficulty. Lath-shaped individuals with rectangular outlines occur, but in most meteorites the mineral is present as minute grains. It forms 22½ per cent. of the meteorite of Shergotty, the remainder of the meteorite being augite and magnetite. It is also an accessory constitutent in

the meteorites of Chateau Renard, Alfianello, Milena, Mocs, and others. Its composition is about that of labradorite. Tschermak regards the mineral as a fused feldspar, while Groth and Brezina consider it a distinct species allied to leucite. Its straight, sharply defined outlines, the existence of striæ, and the absence of any fused appearance make Tschermak's view difficult to accept, though the mineral resembles the feldspars in so many other respects.

Included gases.—All meteorites which have so far been tested give off on heating one or more of the following gases: Hydrogen, carbon monoxide, carbon dioxide, nitrogen, and marsh gas. Comparing the iron meteorites with the stone meteorites in regard to the kind of gases given off it is found that the former are characterized by a high content of H and CO, the latter by an excess of CO_2. The following table of analyses of gases from eight iron and six stone meteorites, quoted from Cohen, gives an idea of the relative quantity of each gas:

	H	CO	CO_2	N	CH_4
Iron meteorites	63.09	20.70	8.12	7.52	0.57
Stone meteorites	17.55	4.15	71.66	2.20	4.17

The volumes of the gases obtained vary from 0.97 of a volume given off from the iron of Shingle Springs to 47.13 volumes collected from the Magura iron. The average number of volumes obtained from the meteorites quoted in the above table is 2.82. The gases in meteorites appear therefore to be under a somewhat greater pressure than that of the earth's atmosphere. It has often been urged that the gases obtained from meteorites by the methods above mentioned may have been absorbed from our own atmosphere. It is known on the one hand that terrestrial rocks give off on treatment gases very similar in kind and quantity to those obtained from meteorites. Thus Wright obtained from one ordinary trap rock ¾ of a volume of gas, 13 per cent. of which was CO_2 and the remainder chiefly hydrogen, and from another, one volume of gas containing 24 per cent. CO_2 and the remainder chiefly hydrogen. Tilden has also recently shown that "the crystalline rocks of the surface of the earth contain very notable quantities

of gas, consisting of hydrogen in preponderance, carbon dioxide, and carbon monoxide in large percentage, and nitrogen and marsh gas in small quantities, with water vapor, but with a practical absence of oxygen. Twenty-five analyses including ancient and modern volcanic and even some metamorphic rocks gave an average volume of gas equal to about four and one half times the volumes of the containing rocks."[1] Further, it is urged that no meteorites have been analyzed as to their gases immediately after their fall. In contrast to these facts it should be noted that the Homestead meteorite was analyzed for gases by Wright within three months from the time of its fall. A second analysis was made a year later in order to test the influence of the earth's atmosphere upon the stone. It was found that very little change had taken place except a slight *loss* of carbonic acid. Ansdell and Dewar in testing the gases of the Pultusk and Mocs meteorites chose stones of those falls which were completely incrusted so that the chances of absorption of gases from the earth's atmosphere might be reduced to a minimum. Yet the results obtained accorded well with those from other meteoric stones and for Pultusk the percentages were remarkably like those derived by Wright in a previous and independent examination of stones of the same fall. There seems, therefore, good reason to believe that the gases obtained from meteorites are brought with them from space and that they have not been derived from the earth's atmosphere.

How the gases are held by the meteorites is uncertain. Wright was inclined to believe that the pores occasionally noted in the silicates of meteorites indicated cavities where the gas was held. Such pores are of too rare occurrence, however, to meet the demands of the problem. The phenomenon seems more like the occlusion of hydrogen by platinum or zinc, and the gases are probably held partly in the intermolecular spaces and partly chemically united. Travers, however, regards them as produced by heat from the non-gaseous elements of the

[1] T. C. CHAMBERLIN: JOUR. GEOL., Vol. VII, p. 558. Quoted from Chemical News, April 9, 1897.

meteorites.[1] The magnetic and nonmagnetic or, in other words, the metallic and stony portions of the Homestead meteorite were tested separately by Wright in order to determine whether these different portions exercised any selective action in holding gases. The investigation gave the following results :

	Volumes	H	$CO+CO_2$	N
Entire stone..........	1.87	50.93	48.07	1.00
Magnetic portion, 0.51	1.48	59.38	38.72	1.90
Non-magnetic portion, 0.97.		30.96	66.96	2.08

The results show no important differences in the gases held by the different portions. By way of caution, attention should be called to the fact that the gases in meteorites may not have been originally present in the form and quantities which the analyses indicate. Thus Wright in making his analyses found CO_2 rapidly reduced to CO through contact with heated iron. Likewise, H, CO, and iron may at a moderate heat reduce the iron oxide present in many meteorites, and thus the character of each be changed. The percentages of the different gases obtained by analyses may be, therefore, more indicative than absolute.

Cohen calls attention to the fact that from artificial irons may be obtained gases corresponding both qualitatively and quantitatively to those obtained from meteoric irons. The following list of analyses illustrates this.

	H	CO	CO_2	N
White, carbonaceous cast iron..........	74.07	16.76	3.59	5.58
Mild steel............................	52.6	24.3	16.55	6.5
Ordinary gray massive charcoal iron....	38.60	49.20		12.20
Gray coke iron........................	32.70	57.90		8.40
Steel.................................	22.27	63.65	2.27	11.36

Finally it should be noted that, according to the investigations of Vogel, Wright, and Lockyer, the spectra of the gases obtained from meteorites show remarkable resemblances to the spectra of comets.

[1] Proc. Roy. Soc., Vol. LXIV, pp. 130–142.

Iron sulphide.—Troilite-pyrrhotite.—The exact form and composition of the iron sulphide which is a common ingredient in meteorites is a question not yet satisfactorily answered. For convenience, Rose's assumption that the iron sulphide of iron meteorites is troilite, that of stone meteorites pyrrhotite, is usually followed, but there are many occurrences which do not harmonize with this view.

The iron sulphide known as troilite is usually found massive, though crystals have been observed which have been referred by Brezina to the hexagonal and by Linck to the isometric system. The color varies from bronze-yellow to tomback-brown. Streak black. Hardness, 4. Specific gravity, 4.68–4.82. Generally found to be non-magnetic, although magnetic troilite has been reported. Cohen suggests that the magnetism may be due to included nickel-iron. The mineral fuses in the reducing flame to a black, magnetic globule. Decomposed by hydrochloric acid with evolution of hydrogen sulphide, but without separation of sulphur. Not affected by copper sulphate or fuming nitric acid. These reagents may be used, therefore, for its separation.

Most analyses show a composition approximating very closely to FeS. Meunier, however, obtained results more nearly in accord with the formula $Fe_{11}S_{12}$. As this is the composition of pyrrhotite he regards the two as identical. The specific gravities which he obtained, however, correspond to those observed by others for troilite, and there seems therefore, some reason to doubt the correctness of his analysis.

Troilite is almost universally present in the iron meteorites. It may be very unequally distributed in a single mass, however, being abundant in some portions and lacking in others. It usually occurs in the form of nodules, but also as plates and lamellae. The nodules vary greatly in shape and size. Rounded and oval forms are common, as are also lens and dumb-bell shapes. In Carlton a star-like form occurs. Smith separated from the Cosby's Creek iron a nodule weighing 200 grams, while one from the Magura iron measured 13^{cm} in diameter. When troilite occurs as lamellae, these are often regularly

arranged parallel to the planes of a cube. Lamellae having this arrangement are known as Reichenbach lamellae. Individual lamellae of this sort average from $0.1–0.2^{mm}$ in width and $1\frac{1}{2}–3\frac{1}{2}^{cm}$ in length. They cross layers of kamacite, and hence must have formed before these. Troilite often occurs intergrown with schreibersite and graphite, and these sometimes surround it. It also often includes nickel-iron.

The fusion and dissipation of troilite nodules during the passage of a meteorite through the atmosphere is a cause of the depressions often to be observed on the surface of both iron and stone meteorites.

The iron sulphide of the stone meteorites occurs chiefly as grains, sometimes as plates, and sometimes in vein-like forms. As mentioned in a previous article, it also occurs in chondri, frequently forming their periphery, while at other times it is in the form of grains. Crystals from the druses of the Juvinas meteorite measured by Rose proved to be hexagonal and to have forms similar to those of terrestrial pyrrhotite. It is largely on account of these observations that the iron sulphide of stone meteorites is considered to be pyrrhotite. On the other hand, the iron sulphide of stone meteorites differs from pyrrhotite in being, for the most part, non-magnetic, and in giving no free sulphur on decomposition with hydrochloric acid. Further, most analyses show a composition corresponding to the formula Fe S.

Schreibersite.—This mineral, peculiar to meteorites (if its possible occurrence in the terrestrial iron of Greenland be excepted) is also one of their most remarkable constituents, since it gives proof that the meteorites in which it occurs could not have been exposed for any long time to the action of free oxygen. The mineral is a phosphide of iron, nickel, and cobalt, having the general formula $(Fe, Ni, Co)_3 P$, though the relative proportions of the metals vary. The normal color is tin-white, but this may readily alter to bronze-yellow or steel-gray on exposure to the air. Hardness 6.5, specific gravity 6.3–7.28. Strongly magnetic, and when magnetized retains its magnetism

for a long time. Very brittle, being thus distinguished from taenite, with which it is often confounded. Another property which distinguishes it from taenite and from cohenite is that it is insoluble in copper-ammonium chloride. It is soluble in ordinary dilute acids and in acetic acid. Does not reduce copper from a copper sulphate solution. Easily fusible before the blowpipe to a magnetic globule. It occurs as crystals, flakes, foliae, grains, and as needles. In the latter form it was long regarded a separate mineral, and was known under the name of rhabdite, but the identity of rhabdite and schreibersite has been proved by Cohen. The needles and plates often exhibit angular outlines. Individual masses of the mineral often reach a considerable size, one from the Carlton iron being 14 ^{cm}. in length. The mineral also forms a considerable portion of the mass of some meteorites, such as Bella Roca, Primitiva, and Tombigbee River. It is the most widely distributed constituent of iron meteorites, aside from nickel iron, and is believed to be usually associated with the latter mineral in the stone meteorites, though its quantity is so small that it has not often been determined. The small percentage of phosphorus usually found in the analysis of stone meteorites is generally referred to this mineral. Schreibersite has been reported in the terrestrial iron of Greenland, but its presence is not proved. Phosphides similar to schreibersite have been made in several ways artificially. The process followed has been essentially to heat iron to a high temperature together with a phosphorus-bearing compound.

Graphite.—This substance occurs in grains of sufficient size for ready examination only in the meteoric irons. In these it is usually in the form of nodules but sometimes occurs in plates or grains. The nodules often reach considerable size. One nodule taken from the Cosby's Creek iron is as large as an ordinary pear and weighs 92 grams. Even larger ones were found in the Magura iron. Toluca, Cranbourne, Chulafinnee and Mazapil are other irons which contain considerable graphite. Graphite has been estimated to form 1.17 per cent. of the mass of

Magura and 0.8 per cent of the Cosby's Creek iron. The mineral is usually associated with iron sulphide. With this it may be intimately intergrown or the one may enclose the other. Its texture is compact rather than foliated. Smith found that the meteoric graphite oxidized much more rapidly than terrestrial graphite on treatment with nitric acid and chlorate of potash. This feature distinguishes it from the amorphous carbon separated from cast iron. The meteoritic graphite is also very pure. Although occurring in nodules of the size described, which must have segregated from the surrounding mass, the ash amounted, in an analysis made by Smith, to only 1 per cent. By ether was extracted a small quantity of a substance made up of sulphur and a hydro-carbon, which constituted the only other impurity. Emphasizing the differences between meteoritic and terrestrial graphite Smith was inclined to believe that the graphite of meteorites must have been formed by the action of bi-sulphide of carbon upon incandescent iron rather than that it was analogous in its origin to terrestrial graphite. Ansdell and Dewar, however, concluded from elaborate comparisons of meteoric and terrestrial graphite that they were similar in origin, and were formed by the action of water, gases and other agents on metal carbides. Whatever its mode of formation the occurrence of graphite in meteorites is of geological interest as proving that graphite may be formed in nature without the agency of life.

Cohenite.—This is a carbide of iron, nickel and cobalt. It has been positively identified in only a few meteorites but is doubtless of common occurrence. Its formula is $(Fe, Ni, Co)_3C$. The mineral is of metallic luster and tin-white color, though readily tarnishing to bronze-yellow. Hardness, 5.5–6. Specific gravity, 7.23–7.24. Strongly magnetic; very brittle. Insoluble in dilute hydrochloric acid and decomposed by concentrated hydrochloric acid only with difficulty. Easily soluble in copper-ammonium chloride. It occurs as isolated crystals on which several forms of the isometric system have been noted; also as grains. Elongated crystals, reaching a length of 8^{mm} are

found in the Magura meteorite. These are arranged parallel to octahedral planes. An iron carbide similar to cohenite is formed in cast iron when the latter is heated to a temperature of 600–700° C. and slowly cooled. Cohenite occurs in the terrestrial iron of Niakornak, Greenland.

OLIVER C. FARRINGTON.

(To be continued.)